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JOURNAL

OF THE

AMERICAN WELDING SOCIETY

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American Welding Society

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The American Welding Society

The American Welding Society is organized to provide united and co-operative action in extending the knowledge of the art of welding and its field of industrial application. The field for further application of welding is enormous, and progress in it is being delayed only by incomplete knowledge and by the confusing and opposing claims of competing interests.

The Society acts as a clearing house for information. Through papers and monthly meetings of local sections of the Society an opportunity is created for the individual manufacturer, engineer, plant superintendent, foreman, operator, etc., to contribute his own knowledge in welding and at the same time receive the benefit of the combined knowledge and experience of all other members of the Society. Special publications in addition to the regular monthly proceedings are issued from time to time giving results of researches, standardization work and other information of value to the members.

CLASSES OF MEMBERSHIP
Extracts From By-Laws

ARTICLE I.

Section 1. Individuals having received the approval of a majority of the Membership Committee shall become members of this Society upon the payment of dues, except in the case of honorary members who shall be elected by unanimous vote of the full Board of Directors.

Section 2. Membership shall be divided into five classes:

Class A. Sustaining members, being individuals or individuals delegated by corporations, firms, partnerships, etc., interested in the science and art of welding, with full rights of membership.

Annual dues $100.00

Class B. Members, being individuals interested in the science and art of welding, with full rights of membership.

Engineers or individuals competent by experience or training to plan or direct welding operations are eligible to this class.

Annual dues $20.00

Class C. Associate members with right to vote but *not* to hold office, except in Sections as may be provided for by the By-Laws of the Sections. Supervising welders, inspectors and skilled operators, with three or more years' practical experience in welding are also eligible to this class.

Annual dues $10.00

Class D. Operating members, who are welders or cutters by occupation, without the right to vote or hold office except in Sections as may be provided for by the By-Laws of the Sections.

Annual dues $5.00

Write to the Secretary for a membership blank.

AMERICAN WELDING SOCIETY

ESTABLISHED 1919

JOURNAL

VOL. 1 APRIL, 1922 NO. 4

BY-LAWS ADOPTED

The amended by-laws as recently submitted to the membership of the Society for vote were adopted by a large majority. The changes in the by-laws were made to suit new conditions arising in connection with section organization and the increased activities of the American Welding Society.

These by-laws are being printed in convenient form and copy will be sent to each member. The printed form will also include the Constitution of the Society.

WELDING PIPES

Mr. Hopping's paper, published in this issue, gives some practical information on the welding of pipes. Both gas and electric welding were employed, and curiously enough one was used to supplement the other. In accordance with their experience, the Philadelphia Electric Company used the good points of each to the best advantage in doing the job. Some of the members of the Society may not be altogether in accord with the theories as set forth for the use of one or the other process, or may wish to supplement the information with their own experience. Discussion is therefore invited.

The papers by both Mr. Malm and Mr. Speller give some valuable information on the same general subject. It is interesting to note that great stress is being laid on the importance of having the proper quality of steel for welding if a good product is wanted. The subject is receiving the attention of our research department, the American Bureau of Welding, and the Bureau's announcement through the Committee on Specifications for Steel to be Welded is awaited with considerable interest.

The paper on the "Applications and Tests of Large Diameter Electric Welded Pipe," by J. H. Nead and R. L. Kenyon, sets forth the results of some very interesting and important tests on electrically welded pipes. Two fields of application for this kind of pipe are discussed in detail. This paper will be presented at the annual meeting of the American Welding Society. We expect to publish in our Journal still other articles on the welding of pipes as the application of welding in this field promises to soon replace other types of construction.

ADVERTISING

Advertising is included in our Journal because there are not sufficient funds available from other sources to defray the expense of publication. The dues from members, of which the National Organization retains half (the other half being returned to local sections), is barely sufficient to pay the ordinary expense of the Society.

Unless we can secure additional advertising (the present amount barely covering one-half the cost of publication), it will be impossible to continue issuing a journal each month and we will be forced to combine two numbers into one.

There is available for publication in the office of the Society a number of very excellent papers, covering a variety of phases of the welding field. We would like to increase the size of the Journal in order to include all of these. However, that is out of question with the present state of our finances.

We believe that advertising in our publication is a good business proposition as it reaches the hands of those interested in welding and the purchase of welding equipment. Moreover, the American Welding Society deserves the support of the industry. Figures compiled by the American Bureau of Welding (the research department of the Society) brought out the fact that the use of welding as indicated by the sale of equipment and welding wire was 2½ times as great in 1920 as in the year 1919. This increase was due in no small measure to the activities of the Society.

Members who are in a position to persuade the officials of their company to take out advertising are strongly urged to do so. Circulation figures and advertising rates may be obtained by writing to the Secretary of the Society.

In closing we wish to express our appreciation to our present advertisers, several of whom contracted for advertising space without requesting circulation figures.

PLANS FOR ANNUAL MEETING

The program of the Annual Meeting of the Society was published in the March issue of the Journal. A successful meeting and a large attendance is anticipated this year. A number of the research committees of the American Bureau of Welding (which is the research department of the American Welding Society) have made substantial progress in their work. A full account of the meetings of these committees will be given in the May issue, as well as reports of the Finance, Publication, Membership and By-Laws Committees.

The technical papers which will be presented at the annual meeting will be published in the April and May issues of the Journal, and thus be made available to all of the members of the Society.

REPRINTS OF PAPERS

There are a number of copies of several important papers available at the office of the American Welding Society. The list of papers are as follows:

"Machine Cutting with Oxygen," by F. E. Rogers of the Davis-Bournonville Co. In this paper the author describes the four leading types of machines which have been ingeniously adapted to meet the requirements of the boiler maker, shipfitter and the sheet metal worker, as also the heavy forge worker. Methods of operations for each type are described which will enable one to secure best results. Cost figures are also given. Twenty cents each.

"Welding Cast Iron Without Studding," by F. L. Paertch, superintendent of welding, Moore Plant, Bethlehem Shipbuilding Corporation. Rules are given for the correct use of the arc. The paper includes also a discussion by several members of the society. Ten cents each.

"Why Malleable Castings Present Unusual Difficulties in Welding," by H. A. Schwartz. In this paper the author discusses numerous metallurgical explanations of the phenomena of malleable. Heat treatment, selection of filler rods, welding procedure, etc., are discussed. Fifteen cents each.

"Proceedings of the Annual Autumn Meeting of the Society and the Addresses Made at This Meeting." Part I includes addresses by several prominent members of the society. Part II includes the "International Aspect of Welding," by President W. H. Wood of the Canadian Welding Society; "Welding Conditions in England with Postscripted Notes on 'Richboro,' Electrically Welded Barge," by Major J. A. Caldwell. Parts I and II fifteen cents each.

"Manganese Steel Rods for Welding." Discussion of Mr. Jones' paper on above subject. Ten cents each.

Note: Special rates for ten or more copies.

RESEARCH ACTIVITIES

STANDARDS FOR ARC WELDING APPARATUS

A meeting of the Sub-Committee on Standards for Electric Arc Welding Apparatus was held in New York on April 7. The Standards as recently drawn up by the Committee were gone over carefully and revised. The report of this sub-committee has been released for publication by the Executive Committee of the American Bureau of Welding and will appear in an early issue of the Journal of the American Welding Society and also be made available in bulletin form. This Committee is working in close co-operation with the Standards Committee of the A. I. E. E., and the latter organization has appointed a sub-committee whose personnel is nearly the same as our committee.

REPORT OF WELDED RAIL JOINT COMMITTEE

The summary of the replies made to the questionnaire sent out by the Committee on Welded Rail Joints, dealing with cast iron, resistance, electric seam and thermit welds is now nearing completion. Printed copies of this report will be sent to the members of the Committee very shortly, and a meeting of the main committee will be held about May 10 in connection with the meeting of the Way Committee of the American Electric Railway Association.

SECTION NEWS

CHICAGO SECTION

The April meeting of the Chicago Section was held Friday evening, April 7, in the usual meeting place, Western Society of Engineers. One hundred and twenty were in attendance. The meeting was addressed by Prof. A. S. Kinsey, who showed four reels of motion pictures on the subject of gas welding, recently prepared by the United States Bureau of Mines in collaboration with the Air Reduction Sales Company of New York City.

The motion pictures covered the various applications of oxy-acetylene welding and cutting, the production and compression of oxygen by the liquefaction process, the manufacture of carbide, production and compression of acetylene and other important details. The general discussion which followed the showing of the reels proved of general interest.

The next meeting of this Section, to be held Friday evening, May 5, in the rooms of the Western Society of Engineers, will be addressed by Mr. Fred. J. Maeurer of the Davis-Bournonville Company, who will deliver a paper on the subject of "Automatic and Hand Cutting With the Torch." This paper will be illustrated.

A list of those present at the April meeting are H. G. Austin, R. C. Bain, D. Baligian, R. H. Bamdt, W. Beach, R. A. Beckman, W. A. Berner, P. Berg, E. L. Blake, G. Boerst, W. M. B. Brady, G. Brown, W. J. Bruce, L. M. Brudzinski, O. W. Budde, W. A. Buenger, J. Bulaw, P. Burns, C. C. Butler, H. S. Card, W. Carlson, E. Casper, J. S. Charpar, R. H. Cocey, G. J. Coleman, L. T. Collins, W. Collins, H. W. Cook, D. S. Coven, F. L. Danzcyk, J. Decker, G. J. Dekker, A. J. Derenzo, L. Desmet, P. Dobb, F. W. Eastman, C. C. Ebright, T. R. Ernest, E. D. Findlay, A. F. Fischer, E. Fitzloff, S. Gavel, M. L. Goodrich, W. H. Gross, G. Gustavson, J. A. Haffman, C. M. Haight, A. H. Homrighaus, E. J. Hrunek, F. Huggins, E. S. Hurd, T. M. Jones, A. C. Kettel, R. E. Kinkead, A. S. Kinsey, J. Kinsock, G. Kirchoff, A. S. Kucharski, H. W. Kurtz, H. Kvelling, B. E. Larson, B. N. Law, J. W. LeGrande, F.

H. Leslie, F. B. Locks, C. W. Madison, L. Mason, R. G. Mason, J. McLuckie, R. McLuckie, J. Mehigan, F. Merrill, C. E. Miner, R. Michler, I. C. DeMuth, O. E. Neill, A. Oliver, W. A. Owens, B. Payne, C. C. Peck, S. Pumley, G. D. Purdon, C. W. Purnell, T. Rafalski, W. V. Rosimowicz, H. W. Reade, J. Remnart, H. E. Reynolds, I. Richards, C. M. Rogers, G. Roths, A. Rozynski, L. Schliecker, J. J. Schmitz, S. Schultz, W. L. Sehnert, S. H. Shaykin, W. A. Slack, A. C. Sossong, D. Stanhope, F. Stichert, C. Stoner, C. Sutalski, E. L. Swangren, C. D. Taylor, W. F. Teichmiller, H. Thessenritz, A. C. Tollman, R. S. Tombaugh, T. B. Toombs, W. A. Voss, M. M. Weist, H. Weiss, W. J. White, P. C. Whitney, G. M. Weigand, T. J. Wiley, H. Wilker, W. Williams.

NEW YORK SECTION

In view of the fact that the annual meeting of the Society will be held in New York during the latter part of April, the New York Section will not hold its regular monthly meeting.

ANNUAL MEETING NORTHERN NEW YORK SECTION

The annual meeting of the Northern New York Section will be held on May 2 and will be followed by a Smoker. No formal lecture will be given at this time, as the meeting will be largely devoted to arranging a program for the coming year and the election of officers.

PHILADELPHIA SECTION HOLDS ANNUAL MEETING

The annual meeting of the Philadelphia Section will be held on April 19 at the Engineers' Club, at which time officers for the coming year will be elected. There will also be a motion picture on "The Making of a Saw."

PITTSBURGH SECTION

A meeting of the Pittsburgh Section was held on April 28, at which time a paper was presented by Mr. Clay W. Roberts, Welding Foreman, Pennsylvania Railroad, Columbus, Ohio, on the "Use and Abuse of Electric Arc Welding in Locomotive Work." The address was illustrated by lantern slides. Mr. Roberts brought out the reason why some electric welds fail. The greatest causes of such failures are inefficient and indifferent workmanship and the little heed taken to have a perfectly clean and properly designed and prepared job. Several examples of failures were illustrated and their causes discussed. Test results were given on a number of samples and also cost figures.

This paper will be published in an early issue of the Journal.

FEBRUARY MEETING OF SAN FRANCISCO SECTION

Several important papers were read and discussed at this meeting on the general subject of welding of pressure vessels. Mr. R. L. Hemingway, Chief Boiler Inspector, California Industrial Commission, presented a paper on the "Welding of Pressure Tanks." Mr. Hemingway's address was very ably presented and well received. He explained in detail the reason for his report to the Commission, recommending that welding be not allowed in the manufacture of pressure vessels. An interesting discussion followed, which developed the fact that the explosions that have occurred recently in this district have all happened on tanks with longitudinal seams butt welded by the oxy-acetylene processes, the tanks having been in service for about two years. The discussion also brought out that no failures have been reported where a vee weld was used. Mr. Hemingway stressed the point that everything possible should be done to restrict the class of mechanic used in welding, and that these men should be licensed, if a scheme could be found practicable for doing this.

Editor's Note:—Reports have come to the office of the Society that the type of joint used was a butt joint of 7/16 inch plate with the edges not bevelled. The metal was simply melted

down on the outside, forming a weld a little over ⅛ inch deep.

Mr. Ryan read and discussed the paper "Arc Welding Ammonia Receivers," by Mr. A. M. Candy. As the result of the general discussion of the meeting, it was agreed by all that considerable good could be gained by cooperation between the American Welding Society and the Industrial Accident Commission on this important question of welding pressure vessels.

EMPLOYERS, ATTENTION

WE HAVE IN OUR FILES THE RECORDS OF MEMBERS WHO HAVE HAD FROM ONE TO FIFTEEN YEARS' EXPERIENCE IN THE WELDING FIELD. IF YOU NEED ANY WELDING TALENT, KINDLY LET US KNOW. THIS SERVICE IS FREE.

POSITION VACANT

V-3. Desire to secure the services of an all-around acetylene welder. American preferred; someone who can take care of trade when necessary. Object, foremanship. We are fully equipped to take care of all classes of work.

SERVICES AVAILABLE

A-8. Acetylene welder, with four years' experience in repair work on all methods, desires position.

EMBLEM

All members of the Society are privileged to wear the Society emblem. Emblems may be obtained in two styles from the Secretary's office. Price, gold-filled, 75c., 14-K. gold, $5.00.

WELDING A 2200 FOOT, HIGH PRESSURE UNDERGROUND STEAM LINE IN CONGESTED CITY STREETS*

By E. L. Hopping**

The Philadelphia Electric Company has recently constructed a 12-in. steam and a 3-in. water return line, about 2200 ft. in length, which presents some unusual features, one of which, the welding of the piping, may be of particular interest to the Welding Society, and is, therefore, described in this paper.

In the construction of the two lines, welded joints have been used wherever possible. In the 12-in. pipe, which is full-weight steel (⅜ in. thick) there are 89 welded joints and 33 flanged joints. In the 3-in. line, which is standard weight steel (¼ in. thick), there are 92 welded joints and 27 flanged joints. The two lines have been constructed in a concrete tunnel having inside dimensions of 2 ft. 7 in. in height and 2 ft. 7 in. in width. The bottom and sides were built first and the pipe lines constructed inside this part of the tunnel, after which the top slab was poured and the excavation above the tunnel filled in.

Each pipe line is supported at about 17-ft. intervals, on sliding or rolling supports. Alternate supports are anchored to the bottom of the concrete tunnel and so constructed that they can slide horizontally to take care of the expansion of the pipe. The purpose of this construction is to hold the pipe in alignment, especially when steam is being turned into the line, at which time there is a tendency for the pipe to bend on account of unequal heating. In the center of each section of pipe, or at intervals of about 135 ft., solid anchors are provided so that the pipe expansion will travel from the center to the ends of the pipe, where expansion joints are provided.

Since it was necessary in running the line through the street, to change the elevation at a number of places in order to clear obstacles, quite a few pockets were formed, which in all cases are drained through traps. After the piping had been assembled and tested, it was covered with 3 in. of magnesia insulation and a layer of heavy roofing felt outside of the insulation.

The purpose of this type of insulation was primarily, to eliminate, as far as possible, the heat radiation into the surrounding soil and thus guard against serious heating of electric cables, which in numerous places are in close proximity to the steam line. With some types of construction the heating of the soil has been so excessive as to cause failures in the electric cables.

Very often underground steam lines have been constructed with screwed and various other types of flanged joints. Such joints

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*Presented at the January, 1922, meeting of the Philadelphia Section, American Welding Society.

**Engineer, Mechanical Department, Philadelphia Electric Co.

frequently become leaky and necessitate tearing up the street, with its attendant inconvenience to the public and expense to the owner of the steam line. It was, therefore, felt in this case to be very desirable, especially on account of the high pressure (130 lb.) gage carried in the line, to make the construction such that it would give a minimum amount of trouble from leaky joints. Another point considered in the discussion of the type of joints to be used in the line was the item of cost. While it was desired to prevent as far as possible, any leaking at the joints it was not considered desirable to spend any excessive amount of money to secure freedom from this trouble.

After a great deal of discussion as to welded joints it was decided that if such a joint were used it would be necessary, in order to secure the maximum protection against failure, to reinforce each joint with an external sleeve welded securely to the two ends of pipe. The accompanying illustration shows in detail the construction of the 12-in. joint. (See Fig. 1.) In some cases where piping has been constructed with only a butt weld at the pipe ends, there have been failures and since failure in a pipe constructed underground in a location such as that selected for this line, might be very serious there was considerable hesitancy in going to the welded type of joint until after the suggestion of using the sleeve reinforcement was made.

A very careful comparative study based on estimates of both cost and speed of construction of the line, was made for three different types of joints, namely, the welded joint, the Vanstone or

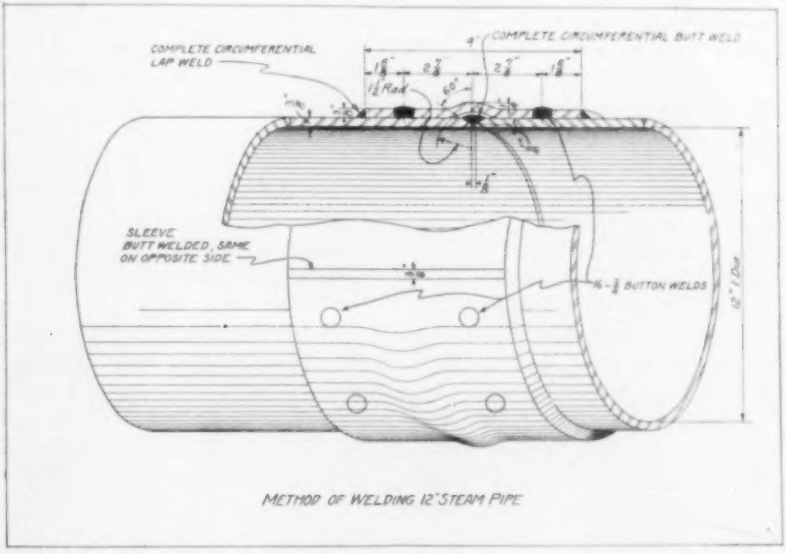
COMPLETE CIRCUMFERENTIAL LAP WELD
COMPLETE CIRCUMFERENTIAL BUTT WELD
SLEEVE BUTT WELDED, SAME ON OPPOSITE SIDE
BUTTON WELDS
METHOD OF WELDING 12" STEAM PIPE

Fig. 1

lap joint and the screwed flanged joint. This comparison proved that the construction work in the field could proceed with as much speed by using the welded joint as by using either of the other types, and that considerable time would be saved in the shop in getting out the piping; especially in cases where a piece of pipe could not be made up until after the adjoining pipe had been laid and the proper dimensions secured in the field. A comparison of the cost of the three types of joints for the 12-in. piping, taking the welded joint as the basis, indicated that the Vanstone or lap joint would cost 10 per cent more than the welded joint, whereas the screwed type of joint would have cost 10 per cent less than the welded joint. A comparison of the joints on the 3-in. steam line showed a little greater saving in comparison between the welded and Vanstone joint, and therefore it was decided to use the same type of joint on the 3-in. as on the 12-in. line.

In view of the trouble which might be experienced with leaking around the threads of screwed flanges, together with the possibility of leaking at the joint between the flanges, it was decided that the welded joint was the best one to use from the standpoint of both cost and reliability. By using the welded joint a considerable saving was effected in the cost of constructing the tunnel as, wherever a flanged joint was used on the 12-in. pipe, it was necessary to enlarge the cross section of the tunnel, and to construct the top of it with pre-cast concrete slabs which could be lifted out, to give access to the joints. Where the welded joints occur it was not necessary to enlarge the tunnel or provide for access to the joint.

In discussing the welding of this type of joint with the National Welding Company, which performed this part of the work, their advice was followed in making the butt weld with the oxy-acetylene process and making the sleeve welds electrically. It was felt that welds made with the oxy-acetylene process would be more dense and therefore better able to withstand the steam pressure than would welds made electrically. Since the welding of the sleeves to the pipe was principally for the purpose of giving mechanical strength to the joint this part of the work was done with the electric process, with which there was much less liability of distorting the butt welded joint, as the area of the pipe which must be heated to a high degree to obtain fusion is localized to the part immediately surrounding the electrode.

In the construction of this line it was necessary at certain points to use steel fittings, and at these points Vanstone flanges were used in making the joint between the pipe and the fittings. It was also necessary to provide expansion joints at about 135-ft. intervals, which necessitated the use of Vanstone joints at these points. In between the flanged joints on the piping there were a number of welded joints which in nearly every case were found to be tight at the butt weld under a test pressure of 750 lb. per sq. in. In all cases where leaks occurred, or where sweating at the weld took

place under the test pressure, the joints were re-welded and again tested. After the butt welds were made tight the sleeves were applied to the joints. Only the first section of piping, containing six welds was tested after the sleeve had been applied and all the joints appeared to be satisfactory. This test was made to determine whether the stresses produced in welding the sleeves to the pipe had in any way affected the butt weld.

In making the butt welds on the piping two sections of pipe were brought together, giving the proper spacing between the ends of the piping, and then one-half section of the sleeve was temporar-

Fig. 2

ily clamped to the pipe ends so as to hold the pipes in proper alignment. This allowed half of the circumference of the butt joint to be welded while the clamps were in position. After the half circumference was completed the half section of sleeve was removed and the piping was turned on its supports so that the other half of the circumference was brought to the top. This method allowed most of the welding to be done from above. There were some cases, however, where bends occurred in the line which would not allow for turning the piping. In these cases it was necessary

Fig. 3

to raise the pipe in the tunnel so that there was 3 ft. between the bottom of the pipe and the bottom of the tunnel, in which space the welder had to perform his work. The welds made from underneath proved in all cases to be as good as those made from above, although it took more time to do the welding from this position, especially when using the oxy-acetylene process. In making the electric welds the speed when working from underneath was almost equal to the speed when working from above. The average total time consumed in making one 12-in. weld, including both the butt welds and welding of the sleeve was three (3) hours.

The difficulties under which some of the work was carried on can be seen by the accompanying illustration (See Fig. 2) giving a view at the top of the trench in which can also be seen a line of telephone conduit, supported by means of cables from overhead timbers. Alongside the telephone conduit in this section there was a 20-in. gas main which also was supported by means of cables from the same timbers. This allowed about 18 in. between the side of the telephone conduit and the side of the trench through which all of the dirt taken from the trench had to be moved. All of the materials for constructing the tunnel and all of the piping in this section of the line were taken through the same space. At this point the pipe is about 12 ft. below the surface of the street, and the obstructions not only made it difficult to get the piping and other materials into place, but allowed very little room for the welders to work.

The other illustration (see Fig. 3) shows the welding of one of the sleeves on the 12-in. line in a trench which was entirely clear of obstructions.

The steam line has been in continuous service, under a pressure of 130 lb. per sq. in., since Sept. 3, and up to the present time none of the welded joints have shown signs of leaking.

The following is the chemical analysis of the 12-in. full weight steel pipe and the 3-in. standard weight steel pipe used in the construction of above lines:

C. —Carbon	.07
Mn.—Manganese	.30
S. —Sulphur	.045
P. —Phosphorus	.100

The electrodes used by the welders are composed of the following:

C. —Carbon	.011
Mn.—Manganese	.017
S. —Sulphur	.032
P. —Phosphorus	.008
Si. —Silicon	trace
Cu. —Copper	.030
O. —Oxygen	.025
H. —Hydrogen	.003
Fe. —Pure Iron	99.874

The same composition was used in the acetylene welding.

Discussion

M. B. KLUTZ*

After going over this proposed work thoroughly with the engineers of the Philadelphia Electric Company we decided to use two welding processes, namely, the Oxy-Acetylene and the Metal Electric Arc.

With Mr. Hopping's kind permission I will review briefly our reasons for using the two processes on this job. Before doing so, however, I wish to have it thoroughly understood that we are in no way prejudiced to either of the aforementioned processes, it being our aim to use the methods which in our mind are best fitted to make a satisfactory job at the least cost.

Our reasons for using the oxy-acetylene on the butt welds and the electric arc on the external sleeve welds were as follows:

First. The butt welded pipe was subjected to a test pressure of 750 lb. per sq. in (hydrostatic pressure) and a working pressure of 150 lb. per sq. in. (steam pressure). While the pipe was still under the test pressure the joints were given severe blows with a heavy hand hammer around the entire circumference of the pipe.

Second. Electric welding is more or less porous and on pressure jobs of this kind it is generally necessary to resort to caulking to close what few pin-holes might show under test. This procedure did not meet with the approval of the engineers in charge.

Third. With the acetylene process it is possible to eliminate this porous condition and to obtain a very ductile weld.

Out of approximately 200 butt welds there were only three or four small leaks which occurred in places where it was so close and hot the welder could stay and weld but a short time. On account of the weld being made at intervals the starting and stopping of the flame caused an excessive amount of oxidation producing a few porous places in welds which chipped out and re-welded.

The external sleeves were welded electrically, because it could be done faster and with less expense and less chance of distortion. With the oxy-acetylene we would have had to be very careful to avoid serious trouble on account of the amount of the heat it would have been necessary to use. With the use of both processes we were able to make a perfect job.

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*Late manager, National Electric Welding Co., and superintendent in charge of welding operations on the 2200-foot underground steam line installed by the Philadelphia Electric Co. in Sansom, Ninth and Filbert streets in Philadelphia.

"PRODUCTION WELDING ON STEEL TUBING AND FITTINGS"*

R. D. MALM†

Production Welding of Tubing

Production welding of steel tubing is confined to the processes of gas welding and electric resistance welding with automatic welding machines, although experiments are at present being conducted to adapt the automatic arc-welder to this line of work.

The Gas Weld Process

In the gas weld process the open seam tube is passed under a multiple jet water cooled welding torch, which melts the outer portion of the steel at the seam and raises the temperature of the inner portion to a welding heat as the tube comes under the influence of the flame.

A set of horizontal rolls exert a lateral pressure on the heated tube at this point and compress the plastic metal at the seam, thereby producing a compression weld in the lower portion and a fusion weld on top, where the steel has been melted by direct contact with the welding flame.

The resultant weld is smooth on the under side, while the top seam is slightly raised, but it requires no further refinement except where a high grade outside finish is desired, in which case the slight seam may be readily removed by passing under an emery-coated polishing wheel.

Electric Resistance Process

The electric resistance process of tube welding utilizes the resistance of the steel to the passage of an electric current of high amperage and low voltage, to produce a welding heat at the seam.

The open seam tube passes under a pair of rolling copper disc contacts which roll on the surface of the tube, one on each side of the seam and close to the edges of the stock.

The heat-producing current passes from one contact through the abutting edges of the stock to the other contact, thus completing the electric circuit and producing a uniform welding heat throughout the entire thickness of the stock at the seam.

Here a lateral pressure is exerted through horizontal rolls which upset the now plastic metal adjacent to the seam and form a true compression weld which is about three times the original thickness of the stock.

The outside burr is later removed by passing under a cutting tube, but the underside of the weld is still reinforced by the stock which is upset in the welding operation.

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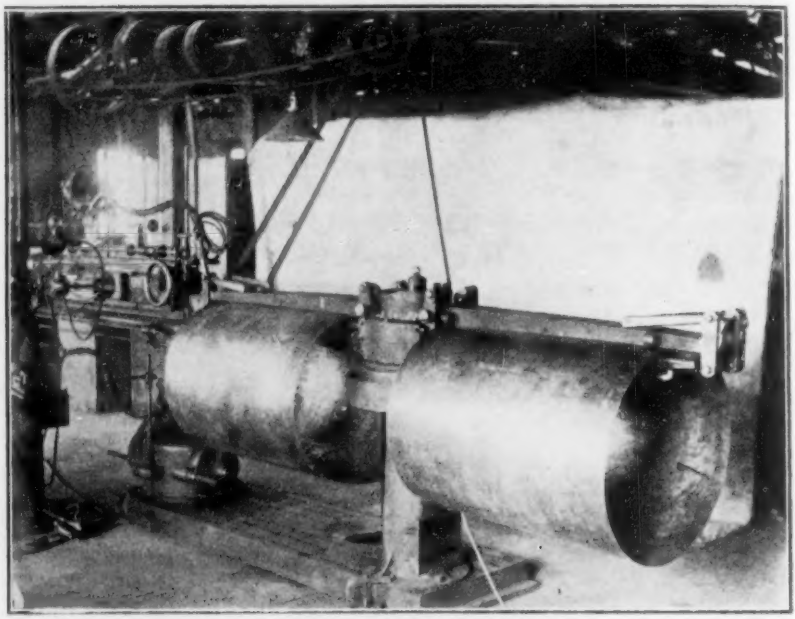
*Presented before January, 1922, meeting, Philadelphia Section.

†Superintendent Standard Welded Parts Company, Cleveland, Ohio.



Barrel Welding Machine in Which Article to Be Welded Is Held Stationary in the Welding Fixture While the Torch Is Propelled Forward Along the Seam

This inside burr can be removed by supplementary operations when necessary, but a much stronger tube will result from leaving this added reinforcement on the underside.

Both Methods Practical

Tubing manufactured by both these processes has found a wide application in industries where tubular steel parts are required and especially where light gage stock is used.

Each grade of tubing has its distinct advantages depending upon the physical requirements to be fulfilled and it would be difficult to draw a dividing line between their respective applications.

Welded Fittings

Special fittings are either blanked from sheets and formed in dies on a punch press prior to welding or else they are built up of sections of pipe with the ends properly milled to form a smooth, close-fitting joint for welding.

The fitting welds are made either by gas flame or electric arc and are a hand operation, since the seams are seldom rectilinear and an automatic machine for executing this type of work would probably be too complex to be practical.

Getting the Right Steel

The main difficulty in production welding of steel parts seems to be in convincing the steel manufacturers of the important effect the chemical and physical properties of steel have on its weldability.

In the past the users have been buying commercial strip and sheet steel without investigating its weldability and as a result first-class equipment and welding gases have been blamed for poor welds which were really due to the quality of the steel. It is hoped that through the work being carried on by the Research Committees facturing commercial welding steel to a new specification.
of the American Welding Society, the steel mills will soon be manu-

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"FUSION WELDING AS APPLIED TO WROT-PIPE JOINTS"*

F. N. SPELLER†

Fusion Welded Pipe at the 1915 Panama-Pacific Exposition

The welding of wrought pipe by the fusion process was fairly well developed before the Panama-Pacific Exposition in 1915 so that the Exposition authorities, in laying out the gas piping system for the Exposition, decided to use nothing but welded joints. They were fortunate in having on hand the service of the Pacific Gas and Electric Company of San Francisco, who had been pioneers in developing the welded joint. This company at that time had many miles of fusion welded gas lines under the San Francisco pavements and, under the leadership of Mr. E. C. Jones, had accumulated considerable experience in the best methods of doing this work.

Wrought steel pipe has been joined successfully in this way for ammonia work, high and low pressure gas lines and for making service connections to both water and gas lines. The result has been a great decrease in the amount of leakage. In order to make a fusion welded gas joint absolutely tight it is advisable to have the fusion weld about $\frac{1}{8}$ in. thicker than the body of the pipe. Both the electric and acetylene process have been used successfully for this work.

Welded Gas Shells for War Service

During the war we designed and manufactured a gas shell made from welded steel pipe in which portions of the heads were welded by the acetylene process. These shells had to be air tight under 250 lb. air pressure when tested under water. In firing these shells at the proving ground very few cases were found where the fusion weld was ruptured. The acetylene process was found to be best

*Presented at the January, 1922, meeting, Philadelphia Section, American Welding Society.

†Metallurgical engineer, National Tube Co., Pittsburgh, Pa.

Fig. 1 Welding a 16-In. Pipe, Showing Operators and Welding Apparatus

adapted for this particular purpose, as it gave a less porous weld than the electric process. We tried both processes and if orders had continued it seemed possible that with a greater amount of practice, we would have gotten as good results with electric welding. Our conclusion at that time was that with comparatively unskilled operators the acetylene process gave the best joint for high pressure gas service.

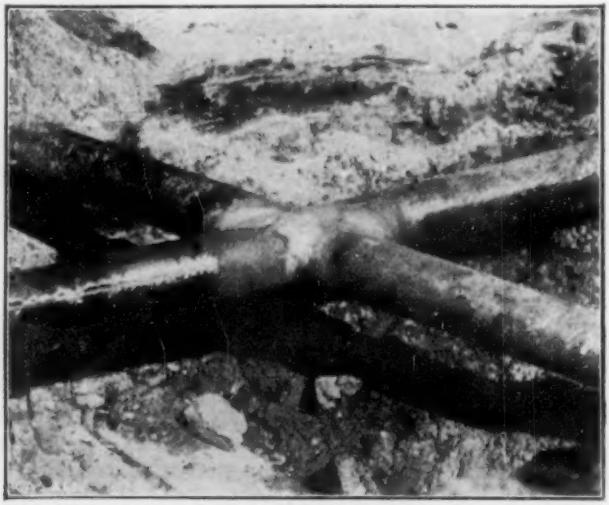

Fig. 2. A Welded Cross in 8-In. Main

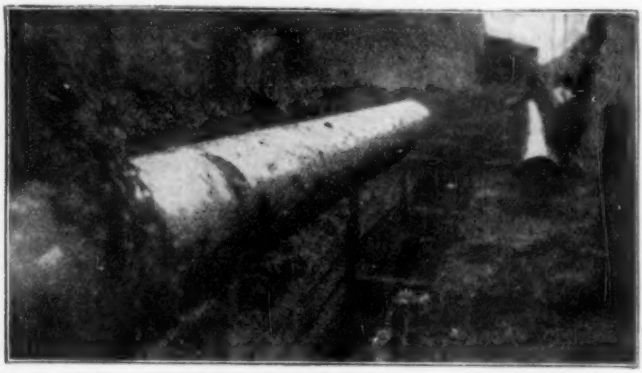

Fig. 3. Length of 16-In. Pipe Weighing Over 1000 Lb., Hanging on Its Weld

1916 Welded Pipe Tests

Some tests were made in 1916 on 8-in. pipe carefully welded together by the electric fusion process, showing that the weld was stronger than the pipe, the average pull required to break the line being 200 tons. The break occurred 4 to 6 ft. from the transverse weld. After testing, the surplus metal of the weld was turned off flush with the outside of the pipe and the pieces repulled with about the same results, two out of three of the samples tested breaking through the weld. In the latter case, however, the weld in two of the pieces proved to be porous under 1000 lb. hydrostatic pressure.

Pipe Steel

Practically all pipe steel in this country is made by the Bessemer process; this steel being usually made especially for this purpose of

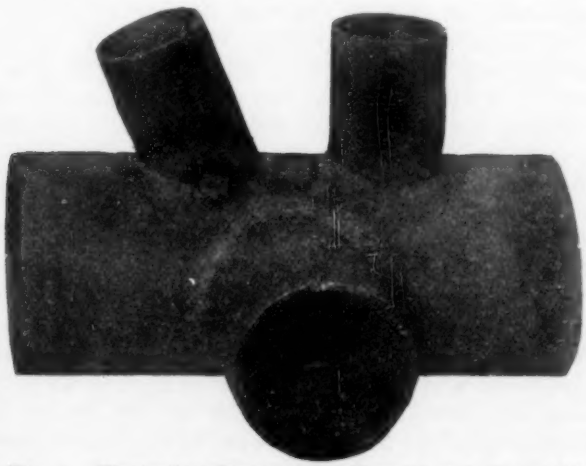

Fig. 4. Illustrating Economy of Material and Ease with Which Laterals Can Be Welded into a Main at Any Angle. Joint Is Gas Tight and Strong as Pipe Itself

a soft welding quality adapted for standing a high temperature without injury. The chemical and physical properties of open hearth and Bessemer pipe steel are given below:

Open Hearth

Chemical Composition		*Minimum Physical Properties*	
Carbon	Not over 0.15%	Tensile strength, lbs. per sq. in.	45,000
Manganese	0.30 to 0.60%	Yield point, lbs. per sq. in.	25,000
Phosphorus	Not over 0.04%	Elongation in 8-in., per cent...	22
Sulphur	Not over 0.05%		

Bessemer

Carbon	Not over 0.09%	Tensile strength, lbs. per sq. in.	50,000
Manganese	0.30 to 0.60%	Yield points, lb. per sq. in.	30,000
Phosphorus	Not over 0.10%	Elongation in 8-in., per cent...	20
Sulphur	Not over 0.06%		

Wrought iron, on account of its irregular structure and high cinder content, is not so well adapted for fusion welding as steel pipe.

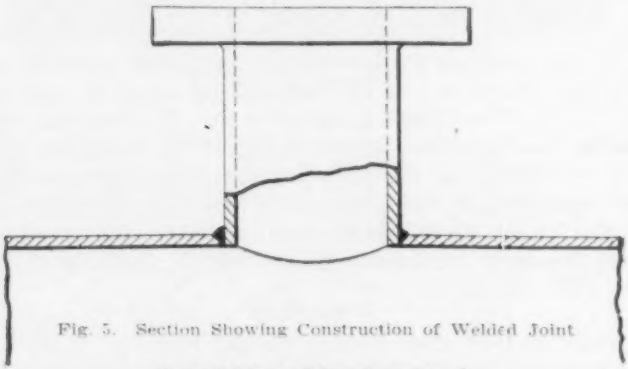

Fig. 5. Section Showing Construction of Welded Joint

Special Specification Steel

Some have suggested that a special quality of pipe steel be developed for fusion welding. If this should prove to be possible there would be the objection that pipe steel must first be *forge* welded and it is quite likely that the peculiar properties that make for good welding quality in forge welding steel are not best adapted for fusion welding. Should this prove to be the case, the seamless steel process now rapidly developing in this country could be used as this permits of the use of almost any grade of steel in tubes and pipe. It might also be found very useful in connection with fusion welding where the sizes required can be made seamless.

The question of the properties required in steel for fusion and forge welding are under investigation by a Committee on "Specifications for Steel to Be Welded" of the American Bureau of Welding. We trust the work of this committee may be of great service in advancing the art of welding, both by the fusion and forge process, as each of these processes seem to have developed a legitimate, although at present, perhaps, rather poorly defined field of use.

Applications and Tests of Large Diameter Electric Welded Pipe*

J. H. Nead and R. L. Kenyon†

Engineering research and investigation are continually opening up new fields and new applications of old methods and processes. One of the most rapidly expanding fields is that of autogenous welding. For a number of years following its commercial development the acetylene process was the only one available for this kind of work. However, with the extension of our knowledge of electricity and its application to new and varied operations electric welding became a reality. Of the several electric welding processes that have been developed, the "metallic arc" process is perhaps the one most widely used. A large proportion of the "metallic arc" welding done up to the present time has been in repairing broken machine frames, building up worn parts, etc. Recently, however, this method has been employed in the fabrication of various finished products and where it has been possible to apply it, a considerable reduction in cost of manufacture has resulted. A particular case of this kind is that of large diameter pipe for low pressure work. There are many uses for such pipe. It has already been used extensively for dredge pipe and low pressure steam lines.

This pipe is made up by rolling flat plates into cylinders of the desired diameter and 5 ft. or more in length. When the pipe is used for steam it was found advisable to bevel the edges. After welding the longitudinal seam several cylinders are welded end to end to make sections of convenient length. For temporary installations, such as dredge pipe, various methods are employed to join sections, while for permanent work, such as low pressure steam lines, the sections are welded end to end in the trench to form a continuous pipe.

The advantages obtained in using such pipe for dredge work are several. In the first place the pipe is lighter in weight than ordinary wrought iron pipe. This is a saving both in original cost, freight, and in cost of handling and installation. Where it is necessary to carry the pipe on supports, a lighter framework can be used. In one large construction job where 30,000 ft. of this pipe was used the pipe was made up in 8-ft. joints and 16-ft. lengths. These sections were provided with a pair of hooks welded to ends of each length. These were tied together with cable or wire. One end of each section was enlarged and slipped over the adjacent section and the joint made tight by driving in shingles. This worked very satisfactory. Fig. 1 shows how the pipe was

*To be presented at the Annual Meeting of the American Welding Society, April 27, 1922.

†Research Laboratory, American Rolling Mill Co., Middletown, Ohio.

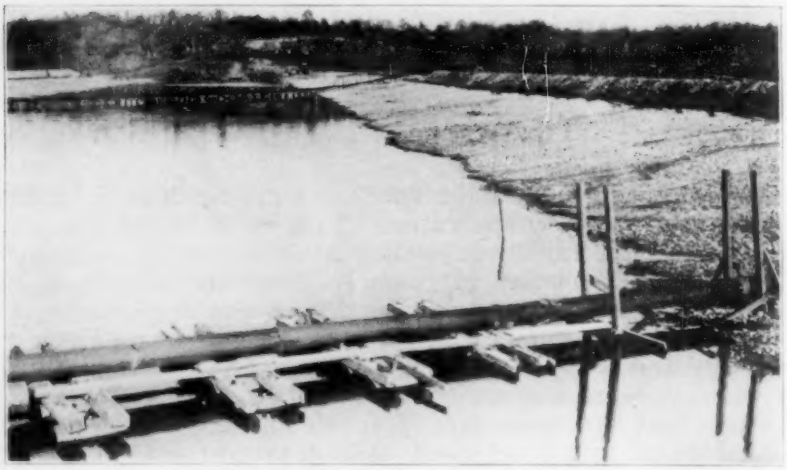

Fig. 1.

used in this installation. The chief engineer on this project has stated that the high carbon electric welded pipe which was used was far ahead of anything that was on the market before and that it has given a service four or five times as long as that of so-called standard dredge pipe which was used almost exclusively heretofore. Another application of welded pipe is in the distributing systems of central heating plants using low pressure steam. The pressure in such systems is generally under 25 lb. per square inch, so that standard pipe of the required size is much heavier than is necessary to withstand the working pressure. For this reason an economy is effected by using welded pipe, which is lighter in weight, easier to handle and lower in cost in larger sizes. It is also generally easier and quicker to make up the welded pipe than it is to buy ordinary steel pipe on the market, especially in the larger sizes.

While the working pressure is low in such installations and the welded joints have ample strength to withstand it, other factors enter in which make the requirements quite exacting. In one installation of 22-in. pipe for a district heating plant it was found that the top of the pipe became hotter than the bottom and the differential expansion tended to open up welded seams if expansion joints were not placed at short enough intervals. No trouble was experienced when expansion was taken care of by joints every 125-150 ft., as at alleys and street intersections, and when the welding was properly done as described later.

The method of installing this pipe is shown in Fig. 2. A concrete foundation about 6 in. thick is laid in the bottom of the trench and carries the pipe supported on rollers to allow for expansion. Sidewalls of brick are brought up on either side the pipe so that

boards laid across the top clear the pipe. The pipe was wrapped with heavy pipe covering. Heavy roofing was wrapped around this, wired on and painted. The space around the pipe is filled with some good heat insulator, such as sawdust or wood shavings. Metal lath is imbeded in a 6-in. cover slab of concrete.

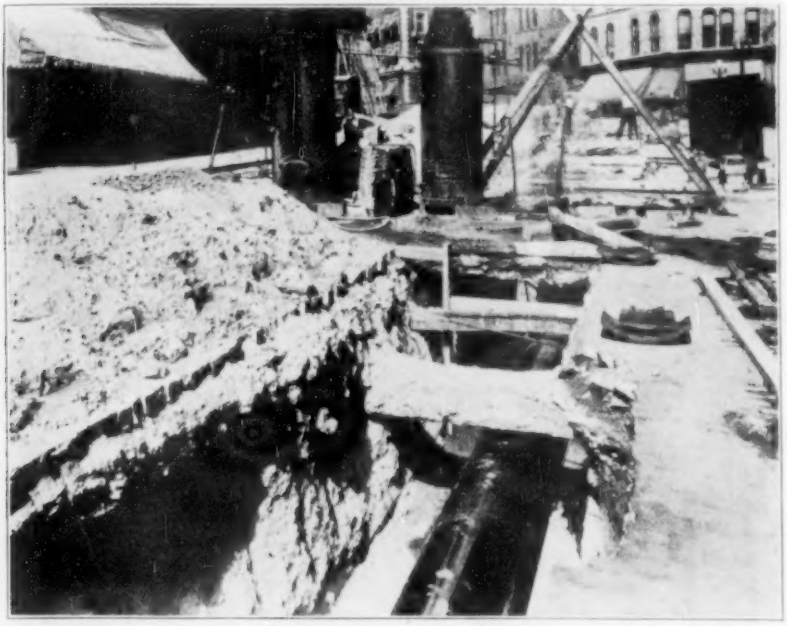

Fig. 2.

In the course of making this pipe it was found that certain precautions had to be observed in order to obtain satisfactory results, and certain methods of testing were tried out in order to develop a means of differentiating between good and bad electric welds. The main trouble encountered was in persuading welders to "cut" clear through the weld. Every weld which was tested where this was not done was found to be greatly inferior in strength to those properly made.

It was found that satisfactory welds could be obtained by separating the edges to be welded about $\frac{1}{8}$ in. and cutting the weld deep and through the plate. When this was done a bead of fused metal was left on the back side of the weld. This was found to be a good index as to whether or not the weld was properly made. Where it is undesirable to have any protrusions of this kind on the inside of the pipe a water cooled copper strip on a mandrel can be held against the inside of the pipe at the weld. This will permit the fused metal "cutting" clear through and yet will give a smooth inside surface to the pipe.

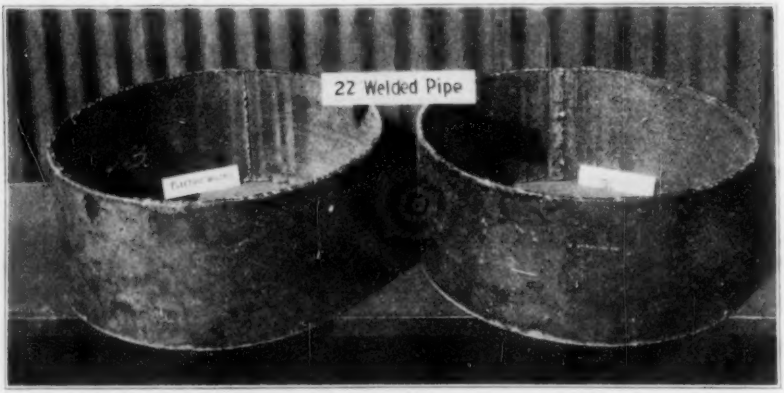

Fig. 3.

The pipe used in the low pressure steam line installation was made from ¼-in. Armco Ingot Iron plate on account of the rust resisting property of this material. The flat plates (approximately 5 ft. x 5 ft. 10 in.) were formed to 22-in. diameter. The edges of the plates were beveled to 37½ deg., thus giving a "single V" type weld with a 75 deg. included angle. The longitudinal weld was then made on the 5-ft. sections by the regular "metallic arc"

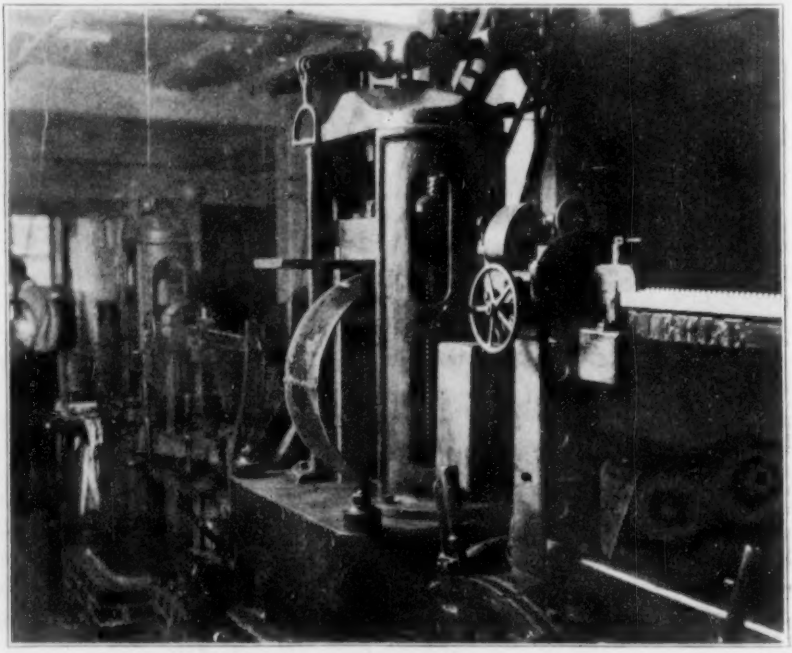

Fig. 4.

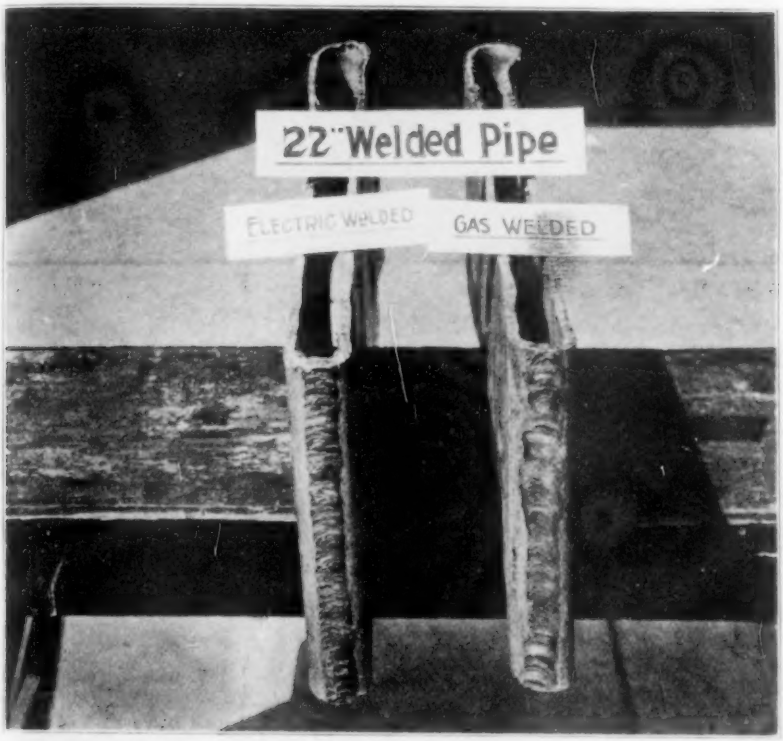

Fig. 5.

process. The welding outfit was of the motor-generator type. The voltage across the arc was 20 volts and the current averaged 160 amperes. Armco Ingot Iron electric welding rods, 3/16 in. diameter, were used for this work. The 5-ft. sections were welded end to end in the shop, in sets of four, the circumferential welds being made in the same manner as the longitudinal welds. In installing this pipe the 20-ft. sections, thus made, were welded end to end in the trench. (See Fig. 2.)

For test purposes samples were cut from the 5-ft. lengths already described. Samples 9 in. in length were prepared from a section in which the weld did not "cut through." Similar pieces were cut from another section which had been properly welded by the method just described. For purposes of comparison another 5-ft. section was made up by oxyacetylene welding and cut into 9-in. lengths for test. The general appearance of the test pieces is shown in Fig. 3. This also shows the bead of fused metal on the inside of the pipe to which reference has been made.

Fig. 4 shows a 9-in. section in the testing machine ready to start the test. The heavy plate is placed between the test section and the head of the machine so as to flatten the cylinder as the head

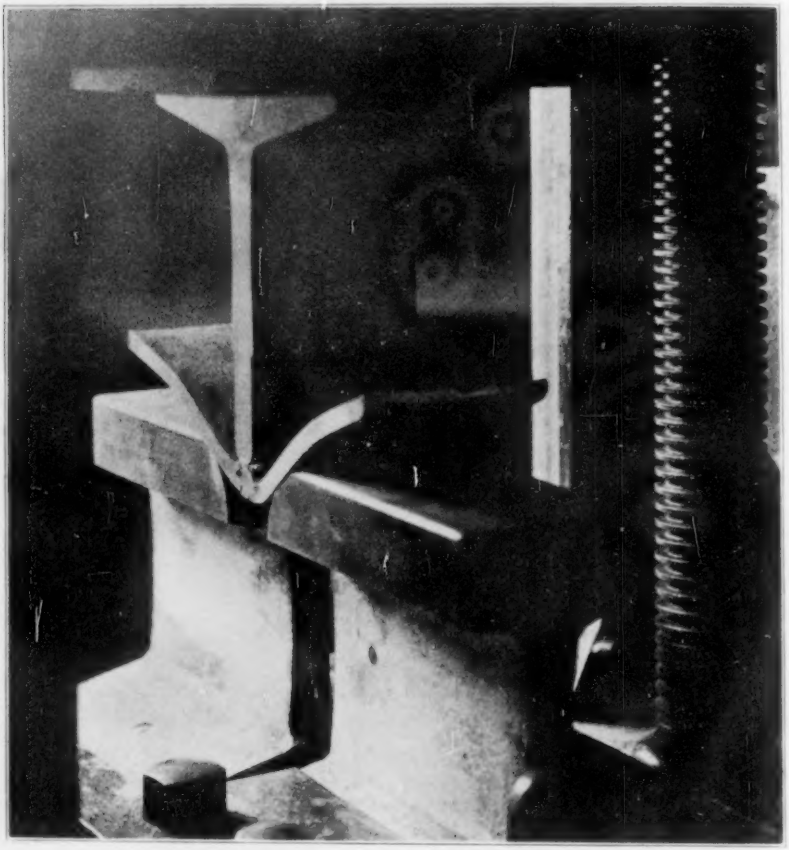

Fig. 6.

is brought down. After running the head down as far as possible it was raised and the flattened section drawn back under the head so as to concentrate the load on the weld. While in this position the load was raised to 68,000 lb. in all cases. The electric welded pipe flattened down somewhat more than the gas welded pipe, but this may have been due to the slightly greater width of the gas weld. In neither the gas nor the electric weld did fracture occur in the weld metal, both opened up slightly, but the fracture was in the affected area adjacent to the weld rather than in the weld proper.

One oxyacetylene and one properly electric welded section were crushed down with a 1-in. block inside the pipe near the weld so as to get the same amount of distortion on each. A load of 68,000 lb. was applied to each as before. The appearance of the test is shown in Fig. 5. In neither case did fracture occur.

In these tests the inside of the pipe was subject to compression

and the outside to tension stresses. As the difference in properly and improperly made electric welds seemed largely to be a case of "cutting through," another test was applied which placed the inside of the pipe in tension. This, as was expected, readily showed up any difference in strength of the welds due to not "cutting through." Specimens were prepared by cutting pieces from the welded sections, 6 in. long and 2½ in. wide with the weld at the center of the 6-in. length. Three such samples were prepared from the oxyacetylene welded pipe and three each from the properly electric welded and poorly electric welded sections. These were tested according to the recommended practice of the American Welding Society for bend tests. In Fig. 6 a test piece is shown in the machine under test. Fig. 7 shows the test pieces in original and final condition.

As the data taken in this test give some quantitative measure of the difference between good and bad electric welds, the results are given in the following table:

	Sample No.	At First Crack		At Maximum Load		Average Maximum Load (Lbs.)	Remarks
		Angle (Deg.)	Load (Lbs.)	Angle (Deg.)	Load (Lbs.)		
Poorly made electric weld (not cut thru)	1			27	2,970		
	2	31	3,800	38	4,450		Sudden crack thru weld at maximum.
	3	41	4,830	77	6,430		
	Av.					4,620	
Properly made electric weld (well cut thru)	1				9,170		These welds slipped to one side in test. Did not crack.
	2				9,830		
	3				10,610		
	Av.					9,870	
Oxyacetylene weld	1	59	6,480		7,450		This weld was not entirely cut thru.
	2				8,440		Cut thru. Fairly good weld. Slipped to one side. No crack.
	3	47	5,920	95	10,200		
	Av.					9,320	Only No. 2 and No. 3 included in this average as No. 1 was not "cut thru."

These bend tests brought out clearly the superiority of the good electric over the poor electric welds and showed the good electric and good gas welds to be about on a par. The poor electric welds were less than half as strong as good electric or good acetylene welds.

The tests also show that single V electric welds, to be properely made, must have the weld metal cut through and form a bead on the under side. Unless this is done the weld will be very deficient in strength and ductility.

As a check on this test, 20-ft. lengths of pipe were tested under 105 lb. per square inch hydraulic pressure before installation and it

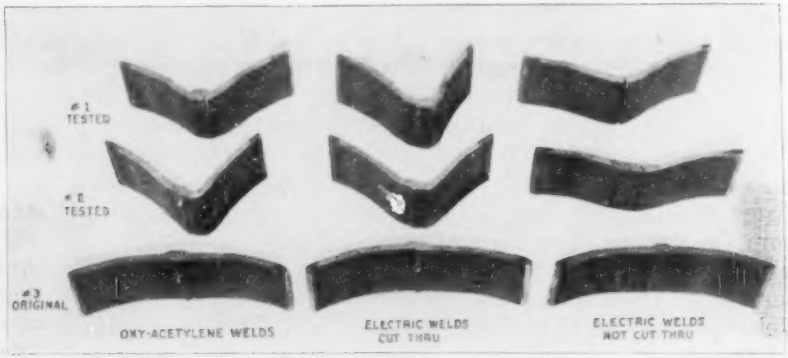

Fig. 7.

was found that tight joints were obtained where the welds were well "cut through," as has been described.

Attention is called to the fact that the dredge pipe and steam heating pipe described was welded by hand by the ordinary "metallic arc" process, and at a saving in cost to the user over standard steel pipe. Automatic welding machines are being developed and with their application to this type of work a still greater reduction in cost should result.

Of the numerous applications of this pipe, only two have been mentioned. The two actual installations cited are evidence of the advantages obtained by its use in place of standard steel pipe. No doubt other uses will be developed as these advantages become better known.

The Oxyacetylene Welding of Copper Plate*

By Alfred S. Kinsey†

1. The welding of copper has always been accompanied with certain difficulties, caused chiefly by the rapid oxidizing nature of the metal when heated and by its peculiar physical characteristics when subjected to heat treatment. The mere joining of the metal by heating it to the plastic state and hammer-welding it has always been practiced, but this was not a strong, non-porous weld. Electric resistance welding also has been used for thin copper where strength was not a factor. It does not seem to be generally known, however, that remarkably fine strength welds of heavy copper may be accomplished by the use of the oxyacetylene torch and the fusion principle of welding.

2. The oxyacetylene welding of copper of ordinary thickness has been practiced for a number of years, but there appear to have been but few attempts made to weld copper thicker than about ⅛ in. It may, therefore, be of value to describe some heavy copper welding in which the joint possessed practically the same density and strength as the adjacent metal.

3. When it comes to making pressure welds of any metal the most important qualifications are strength of joint, close-grained nonporousness of the weld metal and the refinement of the grain along the weld boundaries. These conditions have been rather difficult to obtain with the non-ferrous metals like copper because they are alloyed with such metals as zinc, lead, tin, which cause excessive oxidation. However, it would seem as though these difficulties might have been overcome had there been a better knowledge of the possibilities of oxyacetylene welding.

4. An interesting example of what may be accomplished in the oxyacetylene welding of heavy copper plate is to be found in the recent construction of several copper evaporators for the Swenson Evaporator Company of Chicago.

General Description of Apparatus

5. A view of the completed battery of three evaporators is given in Fig. 1. The four sections of each evaporator are of double-rolled copper 5/16-in. thick by 54 in. diameter by 45 in. long. Each section has a welded longitudinal seam and at the top and bottom of the section are 5/16 in. x 3 in. x 3½-in. angle-iron

*To be presented at the Annual Meeting of the American Welding Society, April 26, 1922.

†Professor of Shop Practice, Stevens Institute of Technology; Advisory Service Engineer, Air Reduction Company.

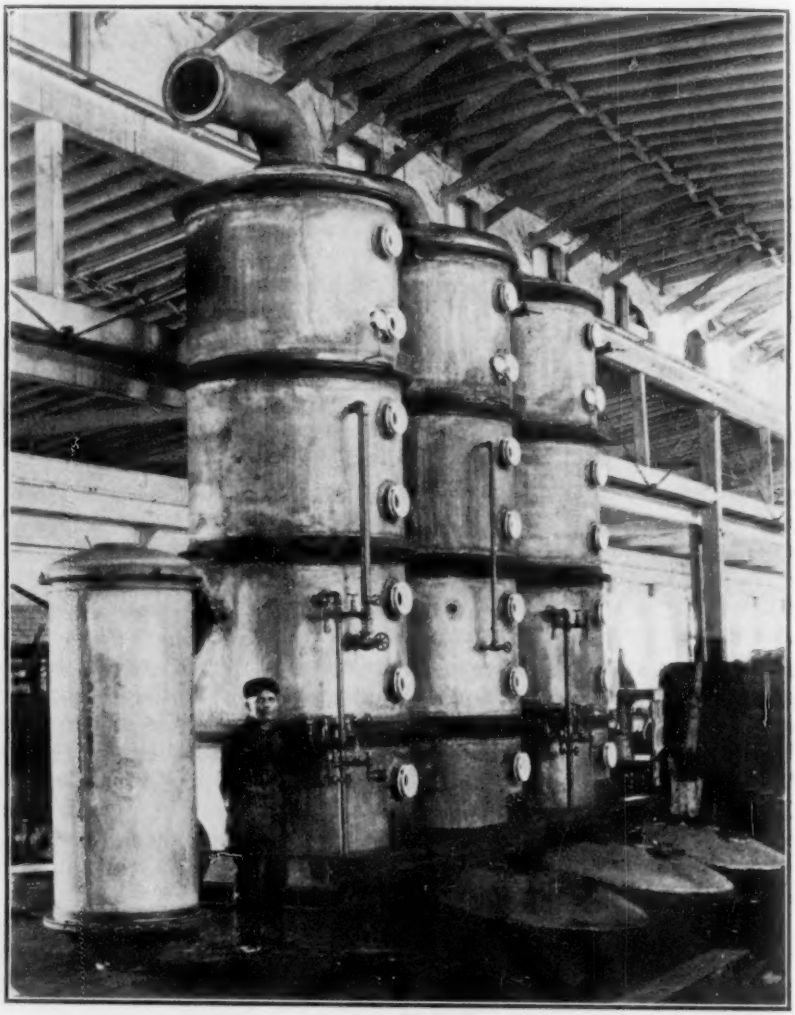

Fig. 1—Copper Evaporators.

rings welded to the copper shell, to provide for bolted flange connections between sections.

6. Inside of the bottom section of each evaporator is a separate shell filled with a nest of tubes, called the Digester, as shown in Figs. 2 and 3. The digester shell was of 5/16 in. copper. The tube-sheets for holding the tubes at each end of the digester were of ½-in. copper and were welded to the shell.

7. The covers for the evaporator stacks and for the digesters were made of copper welded to angle-iron rings.

8. A big copper pipe running through each evaporator was rolled and welded at the job.

9. The main flange connections for the digesters and the evaporator sections were brass castings and were welded in place. In fact, all joints were oxyacetylene welded except the angle-iron connections between the evaporator sections and the digester tube ends, which were expanded in the headers.

Welding Operations

10. WELDING COPPER TO COPPER LONGITUDINAL SEAMS. The welding of the all-copper straight longitudinal seams was accomplished, as shown in Fig. 4. The edges were butted together and beveled at 45 deg. on each side, so that the total angle between bevels was 90 deg. The bottom of each bevel was left with a $\frac{1}{8}$-in. blunt face. A sharp bottom edge would have overheated.

11. The non-rigid method of welding from one end of the seam to the other was used, that is, the edges were separated and then

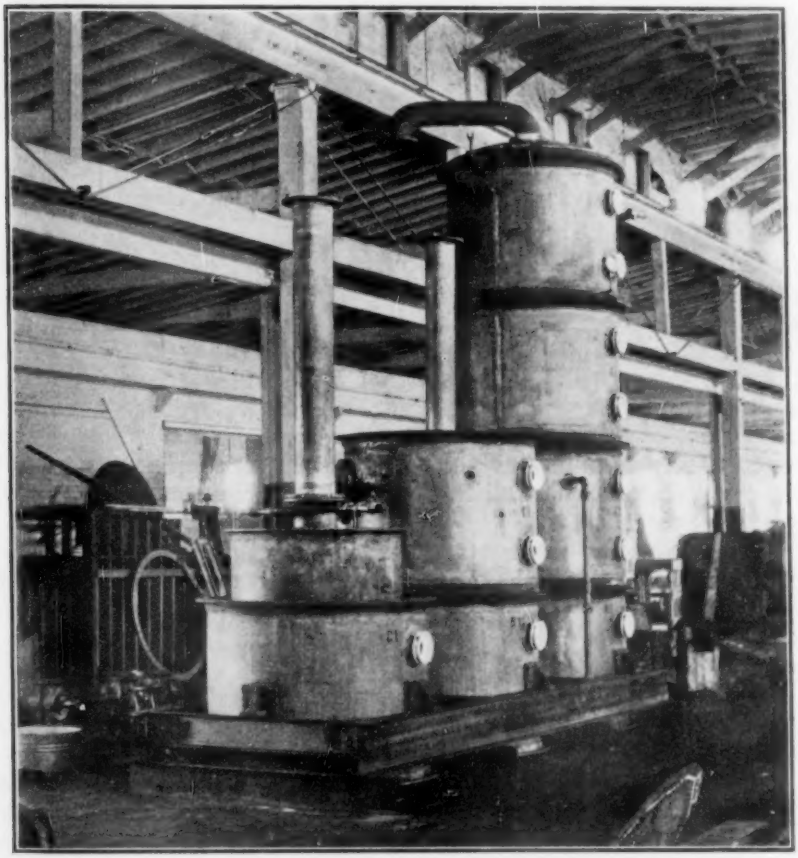

Fig. 2—Copper Evaporators in Course of Erection.

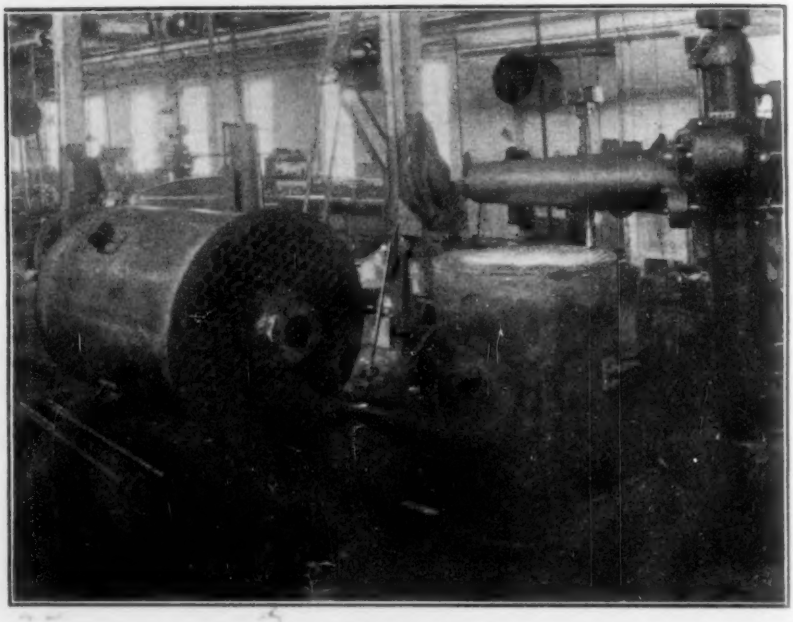

Fig. 3—Copper Digesters.

allowed to close as expansion demanded. A rigid weld is usually made by fastening the two edges in position and making no allowance for expansion and contraction. At first a divergence of about ½ in. per foot for the 5/16-in. copper was found to be proper, but after 8 in. had been welded the expansion was so rapid that the divergence had to be doubled for the rest of the weld. Even then the expansion twist was so fast that it would have caused the weld gap to close soon after the first 8 in. were welded had not means been provided for its control. Fig. 5 shows a simple spreader turnbuckle clamp for this purpose by which it was possible first to hold the weld edges apart and then to let them close gradually as the welding proceeded.

12. The compression strap clamp around the copper shell shown in Fig. 4 should not be confused with the spreader expansion clamp of Fig. 5. The strap clamp was merely a temporary device for keeping the copper shell from springing apart when the welding was being started.

13. After about the next 5 in. beyond the first 8 in. were welded the spreader control clamp was no longer required, the expansion twist then closing the gap at a constant moderate rate.

14. WELDING COPPER TO COPPER CIRCULAR SEAMS. The ½-in. copper tube sheets shown in Fig. 3 were welded to the shell, the diameter of the flue sheet at one end being the same as the outer diameter of the shell, and at the other end the flue sheet

overlapped the shell about 2 in., as shown by the vertical digester of Fig. 3. Therefore, the flush joint was bead welded, and the overlapped joint given a corner weld. The tube sheets were tacked to the shell at four equidistant points before starting to weld.

15. WELDING COPPER TO STEEL CIRCULAR SEAMS. The 5/16 in. x 3 in. x 3½-in. angle-iron, actually steel, flange connections shown in Fig. 6, were welded to the copper shells on the inside for strength and on the outside for tightness. The problem was to prevent warping of the steel rings, which were faced to make a tight-fitting connection. The steel heats up quicker than the copper and the copper cools much faster than the steel.

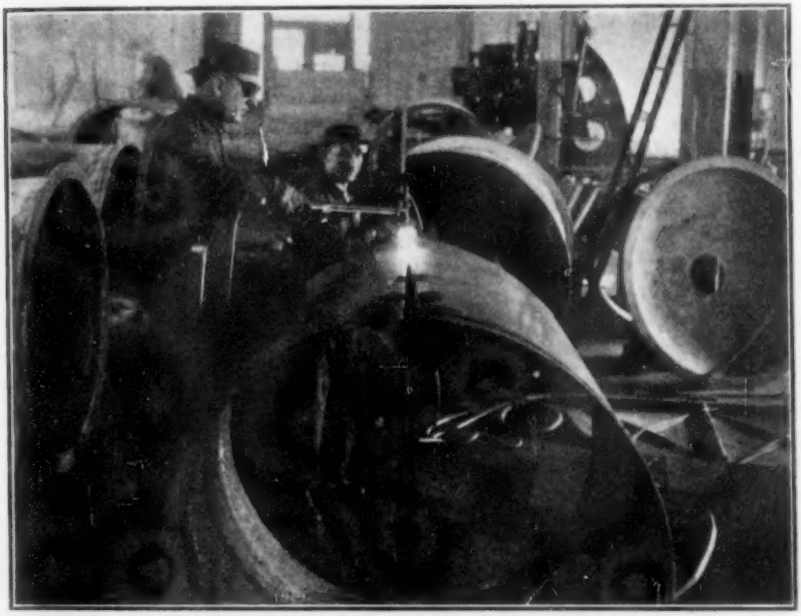

Fig. 4—Welding the Main Seams of Copper Shell.

16. It was planned first to weld the steel and copper on the outside of the shell at A, Fig. 7, but this caused too much warping. Starting the welding at B allowed the copper to expand from A to B, taking the steel ring with it. Then welding at A followed, and while it caused the steel ring to be thrown a few degrees out of level, that is, the outer edge, C, of the ring was pulled downward by the cooling of the weld, this was of no importance. It merely gave the ring a spring which could easily be pulled back to level by the bolts of the flanged joint.

17. WELDING THIN COPPER TO STEEL. An interesting part of the work was the welding of an ⅛-in. copper gasket A, Fig. 8, to the steel ring B, forming the flange joint between the sections of the evaporator. The gasket was 2¼ in. wide. It was needed

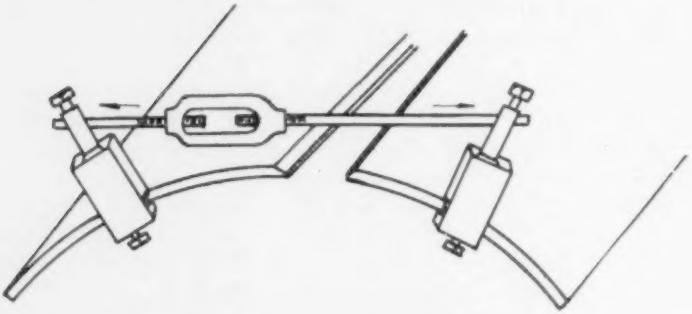

Fig. 5—Expansion Control Clamp.

to insure a tight joint between the horizontal surfaces of the steel angle ring.

18. Any attempts to weld the thin gasket directly from the steel ring at A to the copper shell at C were unsuccessful, because of the unequal contraction between the thick copper shell, the thin copper gasket and the steel ring. It was also very difficult to get the thick copper melted without burning the thin copper. The thin edge of the gasket could not withstand the heat required to melt the thick copper.

19. It was evident that an artificial resistance had to be provided for the thin copper, and that the unequal contraction of the

Fig. 6—Copper Evaporator Sections with Steel Flange Connections.

three metals must be considered. The solutions of the problems therefore were as shown in Fig. 8, where it will be seen (a) that

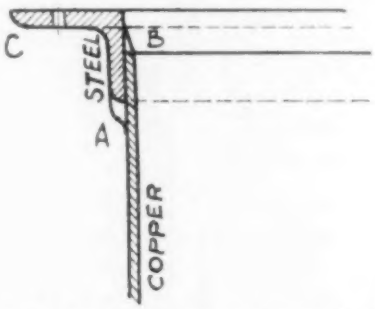

Fig. 7—Angel Iron Ring on Copper Shell.

the unequal contractions were overcome by welding as shown at D from the steel ring around and over the copper gasket and the previous weld at E to the copper shell C, (b) that the thin copper gasket trouble was overcome by bending back the metal, as shown at F, so that it could withstand a much higher welding temperature. Different kinds of welding rods were used, as will be described.

20. WELDING COPPER TO BRASS. Flange connections made of brass castings were welded to the evaporators, Fig. 1, and to the digesters, as shown in Fig. 3. The flanges were from 6 in. to 15 in. diameter. The difficulty in this work was to prevent the oxidation of the zinc in the brass. This was accomplished by first preheating the copper and the brass to the proper temperatures, the copper being the highest, and then flowing the welding rod at the dull metal temperature.

21. THE WELDING FLAME. A standard style of Airco oxy-acetylene welding torch was used. The gases were supplied in the usual steel cylinders, which made them available at any part of the plant.

22. A flame as nearly neutral as possible was used in order to overcome the tendency of the copper to oxidize. The size of torch tip was about two numbers larger than that which would be used for similar thicknesses of steel. This, of course, was necessary because of the rapid heat conduction characteristics of copper.

23. FLUXES. The only use of a flux was when welding with tobin bronze rod, and in that case the flux was of the usual kind sold for copper welding.

24. HAMMER-REFINING. The welds are not hammered, as is sometimes done in the welding of copper. They were quite satisfactory without such mechanical treatment, and the risk was avoided of creating cracks due to the red-shortness of the metal.

25. PARTIAL PREHEATING. Fig. 4 will give an idea of the method used in preheating. A kerosene burner projected a flame

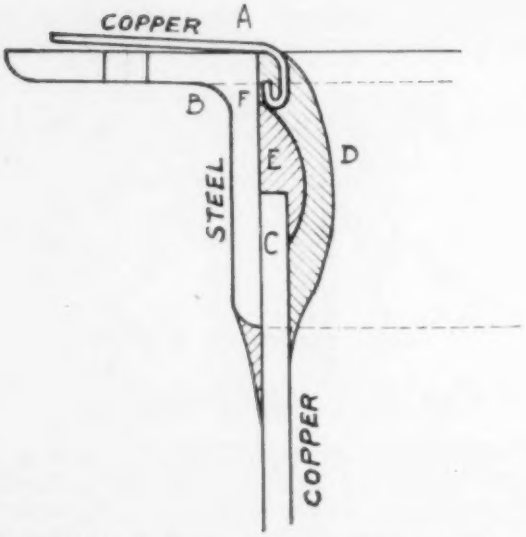

Fig. 8—Welding on Copper Gasket and Insulating Steel Ring.

along under the joint through a trough-shaped flue which confined the heat to a width of about 4 in. each side of the weld. Of course complete preheating of any one of the jobs was not practiced because of the annealing effect it would have on the cold-rolled copper.

26. Preheating was confined to the longitudinal all-copper seams and to the steel ring welds. The preheating flame was kept going all during the welding of the joint.

Welding Rod

27. The most important part of the whole undertaking was the welding rod. Where one kind of rod failed completely, another gave fine results. Where not any one of the rods alone would serve the purpose, two rods of quite different composition used at the same joint did very well. A brief review of this part of the work will be of interest.

28. ROD FOR LONGITUDINAL COPPER TO COPPER WELDS. The rod used to weld the longitudinal seams of the evaporator sections and which we will call Rod No. 1, was of the following composition:

Iron-Copper Welding Rod No. 1

Copper	99.85 %
Iron	.03
Arsenic	.015
Impurities	.105

This proved to be an excellent rod for copper to copper welding. Tobin bronze or phosphor-copper rods made porous welds at these joints.

29. ROD FOR COPPER TO COPPER CIRCULAR WELDS. The overlapping joint at the bottom of the vertical digester shown in Fig. 3 was double welded. It was found that in order to secure tightness of the joint the No. 1 Rod was satisfactory, but it was not strong enough to resist the strains due to the weight of the whole digester, including tubes. So the joint was made of about ½-in. thickness of Rod No. 1 for tightness, covered by an additional ½ in. of a phosphor-copper rod for strength, which we will call Rod No. 2, and which was of the following composition:

PHOSPHOR-COPPER WELDING ROD NO. 2

Copper	99.65%
Phosphorus	.05
Impurities	.30

30. The flush joint at the opposite end of the digester seemed to do well with just the No. 1 Rod.

31. ROD FOR COPPER TO STEEL CIRCULAR WELDS. Some interesting welding rod problems developed at this point. Copper-Iron Rod No. 1 was tried at the joint A, Fig. 7, but it pulled away from the steel on cooling. Then phosphor-copper Rod No. 2 was used, and while it did not come loose from the steel ring it cooled quicker than the copper shell, which caused the phosphor-copper weld metal to crack in many places. The standard tobin bronze rod, which we will call Rod No. 3, proved to be quite satisfactory at this point.

32. At joint B, Fig. 7, it was found that while Rod No. 3 would do the work, Rod No. 2 was much more satisfactory.

33. ROD FOR THIN COPPER TO STEEL WELDS. In welding the thin copper gasket to the steel ring, Fig. 8, it was found best to use Rod No. 3 at D over the bent end of the copper gasket and on over the weld metal E of No. 2 Rod to the inside of the copper shell. This provided a sure means of overcoming any future trouble from leaks, and also insulated the steel ring from the action of chemicals or other materials used in the evaporator.

34. ROD FOR COPPER TO BRASS WELDS. The welding of the brass flange connections to the copper digesters and to the copper shell of the evaporator was accomplished satisfactorily with Rod No. 3. However, there was a tendency of the weld metal to crack from the expansion and contraction of the copper plate, but this was overcome by making the weld about double the normal thickness of weld metal. This made the weld metal stronger than the contraction strains of the copper.

35. TYPE OF WELDING USED. Of the two kinds of welds, the Splash and the Ripple, the ripple weld gave the best results. It was found that while it was easier to make a good looking job with splash welding the weld was almost certain to be porous. It is quite difficult to melt the bottom of the vee and drop some molten welding rod in time to get good fusion. What is likely to happen is

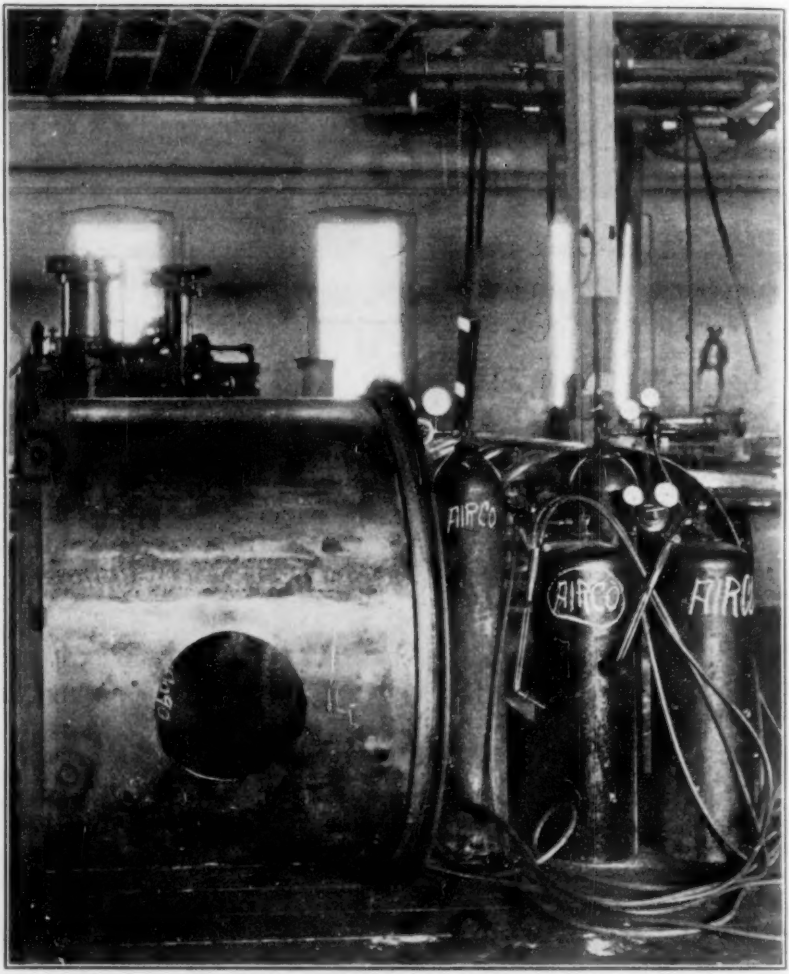

Fig. 9—Welding Torches and Gases

that the melting welding rod will chill before reaching the pool in the vee, and a cold-shut will occur in the weld. Oxides will form at each of these layers and the weld will be too porous for such work.

36. Excellent welds were gotten by ripple welding. A rod 1 in. square was tacked against the bottom of the vee to prevent the molten metal from dripping out. If the vee-strap is not used there will be danger of losing the metal most unexpectedly. The metal will appear to be melted about half way through when it will suddenly drop out, leaving a hole.

37. The ripple weld looked rough and unfinished, but it was strong and nonporous, and when ground smooth its appearance was quite satisfactory.

38. A No. 10 Airco tip supplied heat from the torch quickly enough to keep good control of the molten metal when the welding was done at the best speeds.

39. SPEED OF WELDING. The speed at which the joints could be welded depended largely on the position of the weld, how it was preheated, and the kind of welding used. The all copper 5/16-in. joints were welded at a rate of from 24 to 30 in. an hour, and the circular seams could be done at 20 in. per hour, using ripple welding.

40. REINFORCEMENT OF WELDS. The welds were strong enough to make reinforcement unnecessary. However, they were temporarily reinforced to make certain of the elimination of oxides and then the extra metal was removed.

41. GRINDING WELDS. All the principal welds were ground flush with the surface. There were no blow-holes or shrinkage cracks. The special grinding wheels used on the copper welds were known as "Crystolon grain 36, grade 5, elastic process." The grinding of the welds made a very attractive job, and when completed the joints were hardly visible.

42. TEST OF WELDS. The digester welds were subjected to a pressure test of 65 lb. per sq. in. and the evaporators to a vacuum test of 27 in. There were no leaks at the welds.

Cost of Copper Welding

43. The cost per foot to weld copper 5/16 in. thick was about as follows:

Labor	$.30
Oxygen	.32
Acetylene	.60
Rod	.25
Preheating	.10
	$1.57 per foot

These figures are based on supplying compressed oygen and acetylene in steel cylinders as shown in Fig. 9, and labor at 75 cents per hour.

Advantages of Welded Copper Seams

44. The principal advantages of oxyacetylene welded joints for copper are:

(a) That they are absolutely nonporous and tight. This is of the greatest value where constant high vacuums and pressures must be maintained. It is also of peculiar advantage when the copper container is to hold chemicals, pungent gases, etc.

(b) That they will not need to be repaired. There are no lap joints to be packed or caulked. An oxyacetylene weld in copper is practically of the same nature as the copper adjacent to the weld. It will expand and contract with the rest of the metal, and possess almost the same ductility.

(c) That they need to be no thicker than the adjacent metal, which makes it possible to fit one container into another without the interference of a double thickness of metal at the joint, like the old style lap seam.

(d) That they may be made for any design of copper vessel. Some intricately shaped containers never could be satisfactorily rivetted or brazed, but they can be butt welded.

(e) That they can be made in any shop by an oxyacetylene welder who has had some training in the welding of copper. Instruction in this work may be obtained without charge.

General Notes on Copper Welding

45. Practically all copper a welder would have to handle is made by first being rolled while hot and then cold-rolled or cold-drawn. The grain of the metal is then in the strongest refined condition. Therefore if the copper is melted and then allowed to cool it will be changed from a tough fine-grained metal to a coarse-grained crystalline condition, similar to a casting. An exception to this would be in the making of a weld by the oxyacetylene torch, in which case the molten copper is protected from oxidation by the flame and possibly by a flux.

46. Copper can be hardened by hammering or rolling, or by having some alloy mixed with it when the copper is made. Therefore if a copper weld is hammered it will be hardened.

47. Copper may be annealed, that is softened, by heating it to between 400 to 600 deg. Fahr. and letting it cool quickly in the air. It will not be made any softer by quenching it in water, which is an old practice. Therefore a weld of cold rolled copper will be softer than the adjacent metal due to its heating and cooling.

48. If a weld of cold-rolled copper is required to be as hard as the adjacent metal, it must be hammered. But a welder should understand that copper will stand hammering only when it is at a dull red color. If struck when at a bright red heat a copper weld would crack. Often the annealing of a copper job due to its welding is not a detriment. Then the weld should not be hammered.

49. Copper conducts heat faster than any other commercial metal. Therefore a torch tip about two numbers larger than for steel should be used in copper welding. The weld should be made as quickly as possible.

50. Because of the rapid conduction of heat by copper it is often advisable to use a dam of asbestos cement along each side of the weld to keep the heat from the torch within bounds.

51. Copper in the molten state oxidizes very rapidly when exposed to the air. Therefore the welding torch flame should be carefully kept at neutral.

52. Copper melts at about 2000 deg. Fahr., but this is not the temperature at which it should be oxyacetylene welded. If the molten copper is allowed to become solid again it would "freeze,"

that is, stop flowing at from 50 to 75 deg. Fahr. lower than the melting point, say 1950 deg. Fahr. This is the temperature for welding, that is, when the metal flows sluggishly.

53. Welding rods for copper are often not well understood. They should be used as follows: (a) Iron-Copper Red for tightness of weld. (b) Phosphor-Copper Rod for strength of weld. (c) Tobin-Bronze Rod for welding copper to a ferrous metal like steel. (d) Manganese-Bronze Rod for building up a wearing surface, like that on a locomotive piston. (e) Silicon-Copper Rod for copper that oxidizes very freely.

54. The tensile strength of cold-rolled copper is about 3500 lb. per sq. in. Its elongation is about 35 per cent. When annealed the tensile strength of copper is lowered to about 20,000 lb., but hammering the metal will restore all of its tensile strength.

STELLITE*

Stellite is an alloy of Cobalt, Chromium and other semi-rare metals. This alloy is not steel, since it contains no iron. When Stellite is heated to dull redness, it becomes covered with a film of oxide, which gradually deepens as the temperature increases, finally resulting in a deep blue-black. The metal does not oxidize deeply, even at a white heat.

The physical test of a forged bar of the binary alloy resulted as follows:

Elastic limit	85,000 lb.
Tensile strength	110,000 lb.
Elongation	9 per cent
Modulus of elasticity	30,000,000 lb.
Temperature Coefficient	0.000023° Fahr.

From the above it will be seen that the metal is somewhat stiffer than steel, and notwithstanding its great hardness, it shows considerable elongation. The alloy is made in a variety of hardness and toughness. One alloy is made so hard that it will scratch the hardest and toughest steel produced. By changing its composition and varying the proportions of the metals, a variety of alloys can be produced. Alloys can be used for tools, chisels, table knives, scale bearings, needle valves, valve seats, etc.

We are taking up for discussion the welding and brazing of Stellite in its use for tools in working metals, more particularly lathe tools.

It is needless to state at this time that welding of Stellite is a

*Abstract from paper read by Mr. H. A. Stewart, foreman welder of the National Transit Pump & Machinery Company, Oil City, Pa., before the American Welding Society (Pittsburgh Section), February 24, 1922.

different problem from welding any other type of lathe tools. Its brittleness and high fusion point compel a different method of solution.

On account of the expense of the metal and also because of its brittleness, it is impossible to make a solid tool of this metal. It is customary to make a shank of steel and brazing or welding a tip or working surface of Stellite.

Electric Welding

Great care might be used in this method of welding so as not to destroy the sides of the Stellite. The steel shank is more magnetic than the Stellite, hence an operator will break down the sides and edges of the Stellite when he attempts to unite the two surfaces.

The cross-section areas of the two pieces must be equal in order to perfectly unite the two surfaces.

The iron content of the Stellite is so low that the beads of metal from the electrode tend to unite with the shank instead of the Stellite.

The electric welding of this metal requires a great amount of grinding for clearance preparatory to the weld.

The carbon arc also breaks the sides of the Stellite and causes waste of the metal.

I do not want to create the impression that electric welding of Stellite cannot be done. The above are some of the objections that I have experienced in this method of welding.

Brazing

There are compounds on the market that aid in the brazing of Stellite. The usual procedure is to place the Stellite tip and the shank in a forge and allow them to both soak in the fire and become white hot. A piece of thin copper is placed between the steel shank and the Stellite tip and borax or patented compounds applied freely. The tool should be brought to a white heat or to such a point that the Stellite will soften slightly. The copper is applied freely and allowed to flow behind the borax flux as it runs between the surfaces of the two metals. In this manner the copper will run down and wash any dirt away. At the same time it will exclude the air and hinder oxidation. When the tool reaches the point that it begins to soften slightly, it should be removed from the fire and squeezed gently between a vice or pinchers. Great care is necessary not to bring the tool at too high a temperature, as it is considered necessary not to bring the temperature over 2100° F.; above this temperature, when pressure is applied, the structure of the metal is injured and it will flake off under work.

My experience has been to use the carbo-hydrogen flame instead of the forge. This makes a cleaner and broader source of heat. The carbo-hydrogen flame temperature seems to be about right for work of this kind.

Acetylene

Stellite will readily melt under the acetylene flame. The melted metal can be run into any form or shape desired. I like to melt the metal down into bars. This, as you can readily see, is an excellent method to utilize the broken pieces of Stellite that ordinarily would have to be returned to the makers as scrap metal.

To make a bar, take a piece of 1-inch angle iron about 12 or 15 inches long, gather together all broken pieces too short to use in tool holders and melt into a $\frac{3}{8}$-inch stick on your angle iron. Care must be used at this point not to heat your angle iron to the fusion point, as this will prevent the iron from alloying with the Stellite. A good flux to be used in making the bars is sodium silicate or what is commonly called water-glass. This flux prevents excessive oxidation. A good point to bear in mind in using this flux is to dilute the flux with about one-third water. If the flux is used in the concentrated condition it will bead up under the torch and make the metal porous. Ordinary care ought to result in good bars.

I have taken these bars and placed them in a chamfered shank and welded them in place with a $\frac{1}{8}$-inch spring steel rod, using the sodium silicate as a flux. These tools have been put on our heaviest work and have stood up as well as any other Stellite tools in our shop.

Summary

Our experience has been that the best results obtained in the welding of Stellite is with the use of the oxy-acetylene torch; taking the bars as made from scrap pieces of Stellite, using silicate of soda as a flux and making the shape or form of tool desired.

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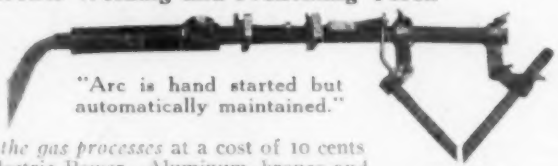

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